Using a Science/Technology/Society Approach To Prepare Reform-Oriented Science Teachers:
The Case of a Secondary Science Methods Course

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Recent science education reform efforts have focused on science instruction that enhances student understanding of the nature of science, enables them to critically analyze scientific information as well as to apply it in real-life situations, and sets them on a path of life-long learning in science. These aspects of science instruction are evident, for instance, in the goals that underlie the National Science Education Standards (NSES) and in the NSES identification of *science and technology*, *science in personal and social perspective*, and *history and nature of science* as science content standards (National Research Council, 1996, p. 13). In order to prepare teachers who can provide the kind of science instruction envisioned in NSES standards, professional preparation of science teachers must be substantially reformed. Reformed preparation of science teachers is indeed vital for the vision of science teaching reform to be accomplished (Raizen & Michelsohn, 1994).

Typically, a critical component of a preservice science teacher preparation program is the science teaching methods course. The usual intent of this course is to help preservice science students develop an understanding of various aspects of science instruction such as pedagogical approaches, management strategies, and assessment techniques. For the most part, these aspects are taught as separate instructional units or

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topics. Since the methods course is taken prior to student teaching and may not include a field component, preservice science students often do not get a simultaneous opportunity to experience how these different aspects interplay in the actual classroom context. Further, the separate topic approach does not mirror the kind of instruction necessary to accomplish the vision of the NSES. According to Kyle (1994), most new teachers are being prepared to conform to the traditional norms operating in schools, rather than to change school science instruction. In other words, traditional science teacher preparation, of which the methods course is a critical component, is hardly aimed at accomplishing reform in school science instruction. What is needed is an approach to connect the major aspects of science instruction within a context that helps preservice science students experience the vision of science education reform and develop an ability to accomplish that vision in their own classrooms.

In order to "reform" a secondary science teaching methods course, I implemented a Science/Technology/Society (STS) approach to engage the preservice science students in scientific explorations around issues, questions or problems drawn from real life situations. Thus, they experienced science learning in much the same way as their high school students ought to, for the reform vision to be accomplished. Various aspects of science instruction such as classroom management and assessment were addressed within the context of these scientific explorations. The semester-long methods course was organized around these explorations which provided my preservice science students with a hands-on/minds-on experience in science instruction that embodied the spirit of current reform in the teaching of science.

Why Use a Science/Technology/Society Approach in a Methods Course?

The Science/Technology/Society (STS) approach is defined by the National Science Teachers Association as the "teaching and learning of science and technology in the context of human experience" (National Science Teachers Association [NSTA], 1990-91). More specifically:

> The bottom line in STS is the involvement of learners in experiences and issues which are directly related to their lives. STS develops students with skills which allow them to become active, responsible citizens by responding to issues which impact their lives. The experience of science education through STS strategies will create a scientifically literate citizenry for the twenty-first century. (p. 48)

Over the last three decades, Science/Technology/Society has been

increasingly recognized as an approach to science teaching and learning that can effectively accomplish the vision of science education reform both in the USA and around the world (Harms, 1977; James, 1986; National Science Teachers Association, 1990-91; Yager, 1991, 1992, 1993a, 1996). Specific results of student accomplishments in science experienced through the STS approach have been extensively documented (Banerjee & Yager, 1992, 1995; Blunck, Giles, & McArthur, 1993; Iskandar, 1991; Kellerman & Liu, 1996; Liu, 1992; Liu & Yager, 1996; Liu, Yager, Blunck, & Seo, 1995; Lu, 1993; Mackinnu, 1991; McComas, 1989a, 1989b, 1989c, 1996; McShane & Yager, 1996; Myers, 1988, 1996; Penick & Yager, 1993; Varrella, 1996; Yager, 1990, 1993b, 1998). Collectively, these published reports of the use of STS indicate measurable improvements in student achievement with respect to mastery of science concepts and processes; the ability to apply science concepts and processes in new situations, particularly those in real-life settings; and understanding and use of the basic features of science (i.e., the nature of science). They also indicate significant increases in student curiosity about the natural and human-made world, significant improvement in student attitudes toward science and science related careers, and significant growth in students' creative abilities relevant to science (such as the quality and quantity of student generated questions, proposed explanations, and methods of testing the validity of those explanations).

The literature cited above clearly attests to the effectiveness of the STS approach in accomplishing the reform vision of NSES. It follows, therefore, that the use of STS ought to become more widespread in school science instruction. One way of ensuring this is to infuse STS approaches in preservice science teacher preparation programs (Tillotson, 1998). STS provides a more desirable alternative to the traditional approaches used in methods courses. If preservice science students experience STS approaches during their preparation, they are more likely to employ them in their own teaching. Thus, they would more likely be able to accomplish science teaching reform with their students. Recognizing the potential of STS for accomplishing the goal of reform, some science educators have recently started infusing STS approaches in their preservice teacher education courses (for example, King, 2002; Monhardt & Veronesi, 1998; Volkmann, 1999). It is with this recognition that I employed an STS approach to organize my secondary science methods course.

Context and Focus of the Study

This study was aimed at exploring the impact Science/Technology/Society approaches have on preservice science students' understanding

of the visions of contemporary science education reform and their attitudes toward contributing to this reform. Three questions guided the study:

> Does engagement with STS approaches help preservice science students better understand the goals of contemporary science education reform?
>
> Does engagement with STS approaches influence the willingness of preservice science students to pursue the goals of reform as science teachers?
>
> Does engagement with STS approaches influence preservice science students' confidence in their ability to accomplish the goals of reform?

The study focused on two of my secondary science methods groups. I taught this secondary science methods course at a mid-sized, comprehensive, urban, commuter public university. The student body at the university consists mainly of adult returning students, many of who are in the process of switching to school teaching as their second career. Most of the teacher education graduates take teaching positions with the local public school system or surrounding suburban school districts. Given its metropolitan location, the student body is extremely diverse with several underrepresented and minority groups (such as African-American, Hispanic, Asian, Greek, Polish, etc.) making up a large proportion of the student population.

The first methods course group consisted of 7 individuals—4 female and 3 male; all were white Americans; one was an inservice teacher while the rest were preservice candidates. The second group consisted of 14 individuals—5 female and 9 male; 4 of the females were white American and one was of combined Cajun, Chinese, and African American descent; among the males, one was Hispanic and the rest were white American; two were inservice teachers while the rest were all preservice candidates. The students in this study were not representative of the university's general student population. This reflects the national trend of underrepresentation of minority groups entering the science teaching profession (Atwater, 1996).

Due to the relatively small number of students in the secondary science teacher education program, the methods course was offered only during the fall semester and most preservice candidates did their student teaching the following spring. Concurrent with the science methods course, students enrolled in 80 hours of clinical experience in school classrooms. The science methods course was the final professional education course they took before student teaching. It offered them the

first opportunity to learn about instructional approaches specific to science before they had to do it themselves as student teachers. Hence, I considered it important to engage students in STS instructional experiences during the science methods course.

Phases of the Science/Technology/Society Approach in the Methods Course

The STS learning experiences I used in my methods course were divided into four phases.

Invitation. During this phase, we brainstormed, searched, and selected issues, questions, or problems (henceforth referred to as TOPIC) based on real life situations, which formed the basis for the rest of our explorations. The topic had to have direct personal, local or social relevance and be able to arouse the interest and curiosity of high school students. We found ideas for current topics on two URLs: www.whyfiles.org and www.sigmaxi.org.

Exploration. Preservice science teachers explored their topics in terms of two components: (1) Identifying critical questions that need to be addressed in order to explore the topic at the high school level; and (2) Gathering and analyzing scientific information and/or data needed to address their critical questions. The exploration phase involved use of the world-wide-web and print resources to locate and collect relevant information. Students identified several agencies, groups, or scientists who were studying issues and questions relevant to their topics and communicated with them electronically to gather up to date information as well as to share their own findings, positions, and action proposals with them. They designed hands-on/minds on investigations that took the form of laboratory experiments, computer analyses, model building, etc. The exploration phase provided the basis for formulating hypotheses, designing explanations, and proposing solutions in the next phase.

Proposing explanations and solutions. During the third phase, preservice science teachers synthesized information to formulate hypotheses, design explanations, and propose solutions. This phase involved communicating information and ideas to peers and to the external experts they communicated with during the exploration phase. Feedback from peers and external experts was used to refine hypotheses, explanations, and solutions. Finally, these were assembled in an electronic presentation format.

Taking action. The syntheses arrived at in the proposing explanations and solutions phase led students to take specific positions and

suggest appropriate actions. In essence, this was the application of their learning. They presented their action proposals to their peers in the methods class; however, in the secondary classroom setting, they would actually involve their students in carrying out these action proposals.

During each of the four phases we discussed and analyzed instructional issues such as assessment of student learning, managing cooperative learning groups, and effective use of modern technology. During the course of the semester the students maintained a journal to record their learning activities and to write reflective analyses of their own learning experiences. Based on their explorations, preservice science teachers created an STS instructional module for a secondary science class that they would be able to use during student teaching.

The first group of seven science methods course students was asked to brainstorm and identify specific topics whose explorations would lead to addressing specific content standards in the State Learning Goals as well as the local school district's Academic Standards. Working as three pairs and one individual, this group conducted four STS investigations:

> *Beetlemania.* An investigation of the Asian Long Horned Beetle infestation in our city.
>
> *Water Quality: Where do we get our water and where does it go when we're done with it?* A study of the drinking water source and post-use treatment of water in a local suburban community.
>
> *What is Death?* An inquiry into the mortal weakness of human beings.
>
> *Tell me what you eat and I'll tell you who you are: A journey in nutrition***.** A study of human diet and nutrition to determine components of a healthy diet.

For the second group, which consisted of 14 members, I presented the news about the creation of a genetically altered, three-legged chicken by scientists at Harvard University. The news clip was drawn from the 'whyfiles' website (www.whyfiles.org) and comprised the *invitation* phase of the project. Students worked in small groups to generate questions arising out of this event that they could feasibly explore in a secondary science class. Once each group reached a consensus on a maximum of five questions, they began the *exploration* phase and continued through the other phases during the course of the semester. The questions they explored were to focus on genetics-related standards within the State Learning Goals and/or the local district's Academic Standards. Thus, unlike the first group, the topic for the second group was the same for

everybody. However, the questions each small group explored were different, hence their explorations took different directions and they ended up addressing different aspects of the content standards.

Methodology

Using a qualitative approach, I analyzed data from three sources to study the impact of STS experiences on my students: reflective journals throughout the semester, class presentation of their STS investigations, and in-depth individual interviews of all students at the end of semester (Figure 1). I formally analyzed all data using an interpretive approach (Guba & Lincoln, 1994) after the end of each semester. During this procedure, complete sentences and paragraphs from student journals and interview transcripts were examined and compared to identify statements that related to the guiding questions. Several statements made by students in their journals and/or interviews are presented in the next section as examples of data that provide insights into the research questions. It is important to mention, from a methodological perspective, that neither student journals nor interviews were included in the course grade. This was explained to students in advance in order to minimize bias in these data sources, which could have resulted from concerns regarding course grades.

Figure 1
Interview Protocol

1. Describe some of the most important lessons you have learned this semester regarding the teaching and learning of science. Why do you consider them most important?
2. What are your most important goals for your students while you teach them science? Why do you consider these your most important goals?
3. In your opinion, what are some of the most critical elements in the teaching and learning of science? Why do you consider them most critical?

Findings

Analysis of the data sources from both groups generally indicated that most students viewed the STS instructional experience positively and were willing to use it with their own students. However, few expressed confidence in their ability to do so. The following student comments gleaned from the three data sources point to the impact of the STS approach with regard to each of the study questions.

1. Does engagement with STS approaches help preservice science

students better understand the goals of contemporary science education reform? The following comments indicate a positive influence of STS:

> The STS approach offers several important benefits including real world experience and relevance to the student's life, but most importantly, STS creates a context in which students find themselves with a need to learn and a use for what is learned.
>
> This experience has opened my eyes and exposed me to an instructional approach that I might never have used if I had not been required to create this STS module. It has shown me that science concepts and processes can mean so much more when they are related to students' daily living.
>
> The STS approach to teaching science has a very clear benefit to the way that science is taught (and hopefully learned). By making science a student-generated problem-based endeavor, it becomes more interesting and relevant for students. If students take ownership of the learning process, they are more inclined to pursue a topic in greater depth and retain the knowledge longer.
>
> All in all this was a positive experience, since now we have walked in the shoes of our students and can understand what is necessary to complete the project. We know the success and pitfalls and can help guide our students to allow them to do their best.
>
> Creating this module has solidified the point in my mind that science information presented by teachers and textbooks has no meaning if it is presented as information without relevance to the students' lives.

2. Does engagement with STS approaches influence the willingness of preservice science students to pursue the goals of reform as science teachers? The following comments indicate a positive influence of STS.

> I hope to use the module during student teaching. It will be difficult to keep quiet about "things" I know about.
>
> I would like to continue working on my STS module. I think with a little effort this module could really work in the classroom.
>
> I can't wait until I get to try some of the stuff with my classes.
>
> I would definitely like to try this—on a smaller scale—with my future students.
>
> This assignment is something that I would not mind trying in my classroom. This can be done with many other topics as well.
>
> As a teacher, I hope to make my students think, question and evaluate things before making up their minds, even if they are difficult to deal with.

3. Does engagement with STS approaches influence preservice science

students' confidence in their ability to accomplish the goals of reform? The following comments indicate students' willingness to try STS approaches, but also reveal their apprehension about being successful with STS.

> Although I plan on incorporating STS approaches in my classroom, I am concerned about management issues.

> On the whole I found work on the STS module to be very stimulating, interesting and informative, but also overwhelming.

This apprehension or lack of confidence is understandable as most students had never experienced science instruction or learning in a way even remotely similar to the STS approach used in the course. Comments from a student in the first group give a clear indication of this limitation:

> Most of us are familiar with the traditional modes of instruction because that is what we are used to seeing. I have seen and experienced science instruction as it is commonly taught in schools, where science information is presented by teachers and textbooks. Up to this point in my life I have been familiar with only the traditional modes of instruction because that is what I have been exposed to. This experience has opened my eyes and exposed me to an instructional approach that I might never have used if I had not been required to create this STS module.

Discussion and Conclusions

It must be mentioned at the outset of this discussion that the STS experience was not unanimously appreciated by the preservice science students in either of the two groups. In fact, during the early part of module development there was a certain degree of resistance in both groups to the STS approach they were experiencing. However, as the modules progressed, students began to be more comfortable with the process, began to recognize its value and potential, and even started enjoying the work. Their summary reflections and module presentations at the end of semester reflected a considerable degree of excitement and satisfaction with what they had experienced and learned about science teaching using the STS approach. There seemed to be a general consensus on the usefulness of the STS approach for secondary science education. Of course, there were those who after the entire experience still claimed to be more confused, apprehensive about the usefulness of the STS approach, and unsure of their ability to employ it in the classes they will teach. There is also the possibility that some of these students were simply going through the motions or jumping through the hoops in order to get through the course but did not develop a real commitment

to what they were learning. Although they were told in advance that reflective journals and interviews would not count toward their course grade, it is likely that some students just wanted to make sure they did not express thoughts, ideas, and feelings that they felt might have an adverse influence on their grade.

It is rather difficult to distinguish genuine from guarded commitment in their comments. However, two possibilities can help: (1) for the few inservice teachers in the two groups, one could find out the degree to which they have started implementing in their own classes what they experienced in this methods course; and (2) for the other students, one could observe them during student teaching and/or the first few years of their career to determine their efforts at implementing what they learned in this methods course. One of the inservice teachers in the second group indicated that

> I began to use the STS model immediately in class. I started with the invitation of asking questions related to the subject and received different types of answers from the students. I was quite surprised at first because the students were responding to the questions from their experience.

This teacher had clearly become convinced of the value of an STS approach to science teaching and put it to work immediately. The quality and enthusiastic presentation of the module on drinking water created by an inservice teacher in the first group suggested very strongly that another practicing classroom teacher was both ready and committed to using the STS approach in science classes.

Of the preservice science teachers involved in this study, 15 went into student teaching immediately following the methods course. Among them, there were at least two strong examples of genuine efforts at implementing STS approaches during student teaching. The first example involved a female student from the second group who did her student teaching in a suburban public high school. She developed and used a genetics module in which her students assumed the roles of genetic counselors and/or DNA analysts. The genetic counselors group was asked to research a genetic disease in detail (exploration phase) and present their findings to a Senate Budget Committee (role-played by the rest of the class) that would determine whether or not special funds ought to be allocated for advancing research on this disease. The committee's decision had to be based on the quality of presentation made by the genetic counselors group (taking action phase). The DNA analysts group was hired by a hypothetical prosecutor's office to analyze DNA from a murder scene. They were to determine whether or not analysis of this DNA sample confirmed the guilt of the suspect beyond reasonable doubt.

The rest of the class in this case acted as the trial jury to decide the guilt of the suspect on the basis of the presentation made by the DNA analysts.

The second example also involved a female student from the second group who did her student teaching in a Chicago public high school. This student teacher developed and used a genetics module focusing on ethical questions in genetics. Her module involved students in participating as characters in a hypothetical genetic counseling situation. Students were given a scenario involving a Jewish college student who is identified as carrier of Tay-Sachs disease. He has a younger brother and a sister, and is engaged to be married to a Jewish woman in three months. His university counselor knows about his carrier status but the student forbids the counselor from revealing this to his fiancée, siblings or parents. Based on some background reading on ethical decision making and genetic information regarding Tay-Sachs disease (which students were expected to research), students were to role-play each of the characters in this scenario and determine the most appropriate course of action for each character as demanded by the questions at the end of the scenario handout. Needless to say, there was great excitement among students as they debated, argued, and synthesized the positions that would be most appropriate for each character. This student teacher also developed and used an environmental science module that focused more on the use of modern communication and information technology.

Students of both of these student teachers learned science in the context of real life issues they were already familiar with and most probably curious about. Thus, it can be safely argued that these two student teachers had already begun contributing to making the vision of the National Science Education Standards a reality. Based upon the data presented here and the example of these two student teachers, it can be argued that this study points to at least the following benefits of organizing a methods course around a Science/Technology/Society approach:

> It "opens the eyes" of preservice science students to alternative, arguably better, ways of teaching science.
>
> It makes preservice science students aware of issues they may otherwise not think about, therefore not learn to deal with (for instance issues related to collaborative group work).
>
> It helps preservice science students better understand the nature of scientific inquiry as they seek answers to their questions during the exploration phase.
>
> It helps preservice science students experience the value and excitement of learning when it is directed by one's own questions and curiosities.
> It brings about a paradigm shift in the science teaching rationale of at

least some preservice science students and enables them to try teaching in a manner congruent with the spirit of the NSES, thus making them agents of reform.

While the majority of preservice science students in this study indicated a willingness to try STS approaches in their classes, it is disappointing to report that there aren't more such examples to show for their willingness. Of course, student teaching is not always an easy time to try out radically new instructional approaches due to many constraints student teachers face as guests in the cooperating teacher's classroom. However, an optimist would take the position that a genuine willingness and a certain degree of confidence can go a long way in creating possibilities for new kinds of teaching in seemingly difficult situations. Now that all of the preservice science students involved in this study have completed their student teaching and have full time positions as science teachers, it will be interesting to visit their classes to study the extent to which they are using Science/Technology/Society approaches, what factors are facilitating their use of STS, and what factors are a hindrance in their use of STS. That makes for a significant follow-up research study to investigate the long term impact of the work reported here.

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